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PERFORMANCE EVALUATION OF DESICCANT SEED DRYER FOR DRYING TOMATO SEEDS

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ABSTRACT

The technical evaluation of desiccant seed dryer and analysis of dried tomato seeds for germination and vigour index has been done in the present study. Dryer can dry seeds in deep bed at safe temperatures for good shelf life, germination and vigour index. The dryer has two chambers one is air conditioning unit and other is seed drying chamber. The dryer has two mode of working i.e. seed drying and desiccant regeneration mode. We can change the flow of drying air from top to bottom and vice versa in seed chamber for uniform drying in deep bed. Desiccant used in dryer is silica gel. Tomato seeds were dried with hot and dehumidified air at five different drying air temperatures i.e. 38, 40, 42, 44 and 46°C and at five different air flow rates i.e., 1, 1.2, 1.4, 1.6 and 1.8 m^3/min.. Germination of tomato seeds varied from 86-64% as temperature varied between 38-46°C, and vigour index varied from 1007.9 - 558.7.

KEYWORDS: Desiccant, Germination, Vigour Index, Regeneration & Dryer

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Original Article

INTRODUCTION

Seed is a material which is used for regeneration purpose. It has importance as it is the cheapest input in crop production and key to agriculture. Crop production largely depends upon the quality of seeds used for sowing. It is estimated that good quality seed to improve varieties can contribute about 20-25 percent increase in yield. The seed needs to be dried in a way that its germination and vigour should not be affected and makes it available for next season crop. The seeds of vegetables are not only costly but are available in limited quantity, so great care is required during drying of seeds.

There are traditional and mechanical methods for seed drying. Traditional methods are open sun drying and mechanical methods include mechanical dryers. But there are drawbacks of these methods. In case of sun drying the drying is unhygienic, slow, labour consuming and uncontrolled. In mechanical dryers the drying is fast but it is costly and energy intensive. The feasibility of the dryer depends largely upon the seed to be dried as well as the climatic conditions. For commercial producers, the ability to process continuously throughout the day is very important to dry the produce to its safe storage level.

In gernal practice seeds are dried at temperature range of 50-60°C, but various studies (Tang and Sokhansang 1993; Correa *et al.*1999; de Valentini *et al.* 1999; K' Opondo *et al.* 2011, Kumar *et al.* 2011) showed that, at this range of temperature germination level falls significantly. But drying air at low temperature is not able to dry seeds as its relative humidity is high. Othmer (1979) in his study found that seeds can be dried by using dehumidified air. Various studies reported the seed drying using dehumidified air at low

temperature (Kundu *et al*. 2001, Adapa *et al*. 2002, Dhaliwal *et al*. 2009, Ondier *et al*. 2010), but the drawback associated with these studies was loss of dehumidified air to the environment, which decreases the efficiency of dryer. To avoid loss of dehumidified air to environment closed circulation dryers were also developed and were reported in studies (Dhaliwal *et al.* 2009, Ondier *et al*. 2010) and in these studies drying was thin layer drying. In present study performance evaluation of closed circulation desiccant seed dryer for deep bed drying has been done. Tomato seeds were dried using silica gel as desiccant. Qualitative analysis of tomato seeds dried at various drying air temperature and flow rates in this dryer were also done.

MATERIAL AND METHODS

Experimental tests were carried out at Department of Processing and Food Engineering, College of Agricultural Engineering and Technology and Seed Science and Technology CCS HAU, Hisar. Seeds of tomato were taken for the studies which were purchased from Department of Vegetable Science CCSHAU, Hisar. The moisture content of seeds was measured by hot air oven method as per (ISTA, 1986).

Analysis of Dried Seeds

Qualitative properties of seeds like germination percentage and seed vigour index of dried seeds were calculated as per International Seed Testing Association (ISTA, 1996) rules and as per formula given by (Abdul Baki and Anderson, 1973).

Table 1: Physical Characteristics of Tomato Seeds

S.No	Physical Characteristic	Value
1.	1000 seed weight (g)	2.20
2.	Bulk density (kg/m^3)	349.1
3.	True density (kg/m^3)	1014.3

Determination of Germination Percentage

Germination percentages, using 3 replicates of 50 seeds, were determined by placing the seed samples in 90 mm Petri dishes on 90 mm filter papers, moistened with distilled water in accordance with the International Seed Testing Association (ISTA, 1996) rules.

Seed Vigour Index Determination

To calculate vigour index ten seedlings from each replication were selected at random after germination, and seedling length was measured. The same seedlings were dried at 80± 1ºC for 24 hrs and weighed. The mean seedling length and dry weight were used for determination of Seed Vigour Index using two different methods (Abdul Baki and Anderson, 1973).

Specification and Working of Dryer

Dryer has two chambers, chamber 1 is air conditioning chamber and chamber 2 is seed drying chamber. Chamber 1 consists of electric heater, air distributors, desiccant bed and heat exchanger. Chamber 2 consists of seed bed and wire mesh. Chambers are connected through G.I pipes of 50 mm diameter with gate valves. Dryer is attached with two solar plate collectors which provide hot air during regeneration. 1.5 hp blowers is used to circulate air in dryer at flow rate

of 1.8 m^3/min.

Dryer has two modes of working i.e. seed drying and regeneration mode. In seed drying mode dried and dehumidified air flows between chamber 1 and 2. The hot drying air enters chamber 1 passes through heat exchanger first because desiccant doesn't absorb moisture from hot air. After it passes through desiccant it gets dehumidified and again heated to desirable temperature by electric heater provided in chamber 1. Heated and dehumidified air is then supplied to seed drying chamber. The drying air after gaining moisture from seeds re-enters in chamber 1 and gets conditioned. In seed drying mode, drying air flows in closed loop i.e. between chamber 1and 2. Desiccant gets saturated after drying of seeds, which needs to get regenerated. In desiccant regeneration mode, hot air is sucked from solar plate collectors and pumped to chamber 1, where it brought to desirable temperature using temperature sensor and heater. Hot air is then passes through desiccant take its moisture and exhausts in environment from valve provided at bottom of chamber 1.

Design of Experimental and Data Analysis

Response Surface Methodology (RSM) was used in designing the experiment (Cochran and Cox, 1957). The central composite rotable design (CCRD) for the two independent variables was performed. The independent variables were air flow rates (A) and drying air temperature (B). The independent variation level is shown in table 1 below.

Table 2: Process Variables Used in the Central Composite Design for the Two Independent Variables

Process Variables	Code	Variables Variable Codes				
		-1.414	-1	0	+1	+1.414
Flow rate (m^3/min)	A	1	1.2	1.4	1.6	1.8
Temperature(⁰C)	B	38	40	42	44	46

The levels of each variable were established according to literature data and preliminary trials. The outline of experimental design with the actual value is presented in table 2.

Table 3: Response Surface Experimental Design in Terms of Coded Levels and Actual Levels

Run	Coded Values		Actual Values	
	A	B	Flow Rate (M^3/Min)	Temperature(⁰C)
1	+1	+1	1.6	44
2	+1	-1	1.6	40
3	-1	-1	1.2	40
4	-1	+1	1.2	44
5	-1.414	0	1.0	42
6	0	-1.414	1.4	38
7	+1.414	0	1.8	42
8	0	+1.41	1.4	46
9	0	0	1.4	42
10	0	0	1.4	42
11	0	0	1.4	42
12	0	0	1.4	42
13	0	0	1.4	42

Dependent variables were Germination percentage, seed vigour index and rate of moisture evaporation. Response surface methodology was applied for experimental data, a statistical package of design expert version 10.0 (Trial version for 31 days) for generation of response surface plots and for statistical analysis of experimental data was

used. The results were analyzed by a multiple linear regression method which describes the effect of variables in the models derived. Experimental data were fitted to the selected models and regression coefficients obtained. The analysis of variance (ANOVA) tables were generated for each of response functions. The individual effect of each variable and also the effects of interaction term in coded levels of variables were determined.

Total number of experiments = $2^{\text{no. Of variables}}$ + 2 x no. of variables + central points

Total number of experiments for 2 variables = $2^2 + 2 \times 2 + 5 = 13$

Five different levels for each experiment in coded form are as follows:

$-\alpha$, -1, 0, + 1, $+\alpha$

Where, $A = 2^{\text{no. of variables}/4} = 2^{2/4} = 1.414$.

RESULTS AND DISCUSSIONS

In desiccant drying of tomato seeds, operating conditions like drying air temperature and air flow rate influence the qualitative properties of seeds in a complex fashion and effects are listed in table 3. The rate of moisture migration from center to surface of seed is influenced by temperature, pericarp thickness, chemical composition of seed and seed coat permeability. The rate of moisture removal from the surface of the seed is influenced by degree of surface saturation, relative humidity and temperature of drying air. If evaporation from the seed surface occurs too rapidly it can damage the embryo, therefore seed should be dried carefully to minimize damage due to heat (Philpot, 1976). In contrast, if moisture elimination takes place too slowly it may favour invasion of pathogens (Harrington, 1972). In the present study, the mechanical desiccant seed drying reduced seed moisture from 20.6 % (wb) to 8.66 % in 2.5 hours. While on the other hand in shade drying moisture content reduced to same level over a period of days. The removal of moisture was fast in mechanical desiccant drying as compared to shade. The variation in moisture content of tomato seeds at mean drying air temperature and mean air flow rate inside dryer is shown in graph. It was seen that moisture removal at initial stages was higher as compared to later stages, this was due to surface moisture, similar results of seed drying were reported in literature (Dhaliwal *et al.* 2009, Ondier *et al*. 2010).

Germination Percentage

The quadratic model obtained from regression analysis for germination percentage of tomato seeds in terms of coded level of variables was developed as follows:

Germination %= 179.49 (flow rate) + 64.76 (temperature) – 1.07 (flow rate) x (temperature) – 46.81 (flow rate)^2 – 0.77 (temperature)^2 – 1363.82

Regression model fitted to experimental result of germination percentage showed the P- value for the lack of fit as 0.0316 which implies the lack of fit was non-significant and the model F-value of 4.81 implies that the model is significant. The value of R^2 was found to be 0.77.

Figure 1 show that the germination percentage of tomato seeds firstly increased with increase in drying air temperature then started decreasing with increase in drying air temperature. In this study germination was also affected when the air flow rates was changed to very low or very high values. This was happening because drying takes time as moisture was not adsorbed properly at low and high air flow rates. Similar studies were reported by (Gowda *et al*., 1990,

Sarada *et al*., 1994, K' Opondo *et al*., 2011, Christinal *et al*., 2012)

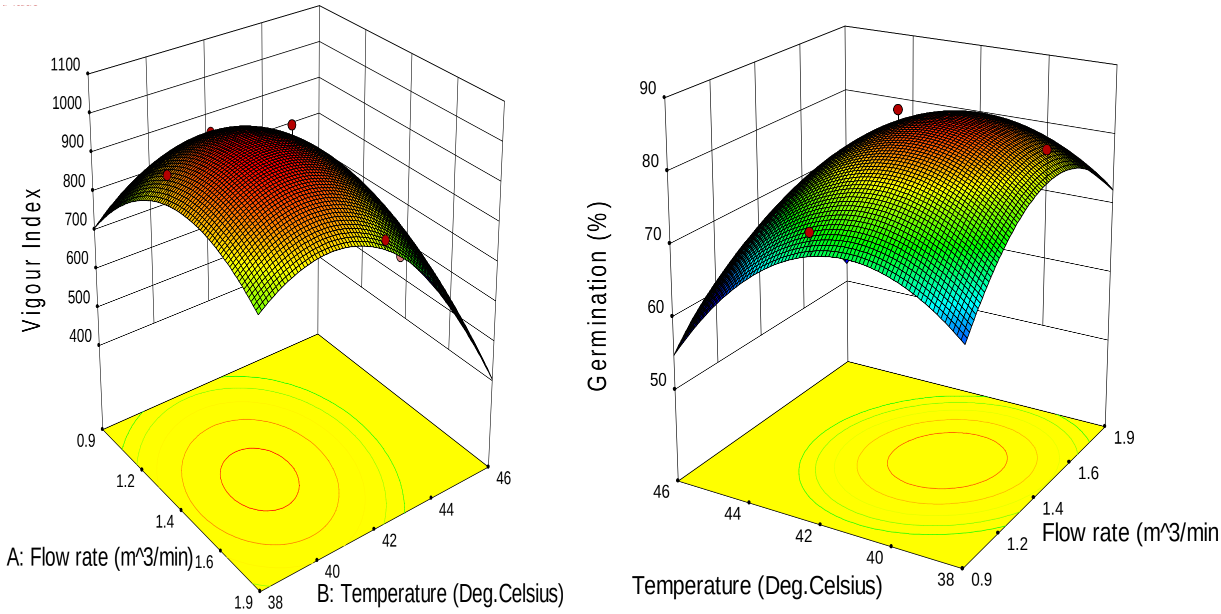

Figure 1 & 2: Effect of Drying Air Temperature and Air Flow Rate on Germination and Vigour Index of Tomato Seeds

Table 3: Effect of Drying Air Temperature and Air Flow Rate on Germination and Vigour Index of Tomato Seeds

Experimental Runs	Flow Rate (M^3/Min)	Temperature(^{0}C)	Germination %	Vigour Index
1	1.6	44	74	781.4
2	1.6	40	78	901.7
3	1.2	40	74	836.9
4	1.2	44	72	751.7
5	1.0	42	76	853.5
6	1.4	38	84	991.2
7	1.8	42	76	877.8
8	1.4	46	64	558.7
9	1.4	42	86	1007.9
10	1.4	42	86	1007.9
11	1.4	42	86	1007.9
12	1.4	42	86	1007.9
13	1.4	42	86	1007.9

Vigour Index

Seed vigour is an important qualitative criterion which needs evaluation for the performance of seeds in field or in storage..

The quadratic model obtained from regression analysis for germination percentage in terms of coded level of variables was developed as follows:

Vigour Index = 2728.25 (flow rate) + 1239.58 (temperature) – 18.7 (flow rate) x (temperature) – 669.30 (flow rate)^2 – 14.97 (temperature)^2 – 26077.5

The significance of coefficient of fitted linear model was evaluated by using F-value and P-value. Regression model fitted to experimental result of vigour index showed the P-value for the lack of fit as 0.0095 which implies the lack of fit was non significant and the model F-value of 7.60 implies that the model is significant. The value of R^2 was found to be 0.84. Regression analysis showed that vigour index was significantly affected by linear ($P < 0.001$) effect of drying air temperature, while also significantly affected by linear ($P < 0.001$) effect of air flow rate.

It can be seen from Table 3 and Figure 2 that value of vigour index for tomato seeds decreased at higher value of drying air temperature. Though temperature was same but effect of flow rate could be significantly felt on the vigour index, at lower flow rates drying time of seeds increased therefore they exposed to hot air for longer period which affect seed quality while on the other hand if evaporation from the seed surface occurs too rapidly it can damage the embryo, therefore seed should be dried carefully to minimize damage due to heat (Philpot, 1976). Similar values of vigour index for tomato seeds were reported in literature (Kumar *et al*. 2018, Raithak *et.al*.2013)

CONCLUSIONS

The eloquent conclusions drawn from the results of the study are:

- Moisture content of tomato seeds was decreased from 20.6 % - 8.66 % in 2.5 h.
- Germination of tomato seeds varied from 86%- 64%.
- Vigour index of tomato seeds varied from 1007.92 – 558.72.
- Generally vegetable seeds are dried in shade, which takes 4-5 days for drying, but using this dryer, it was found that seeds could be dried in 2-4 hours. Also the shade drying is not effective when ambient relative humidity is high but in case of this dryer there was no affect of ambient relative humidity on drying process.
- In this dryer, drying occurred at low temperature (38-44⁰C) so there was no effect on the germination of seed.
- Deep bed drying was carried out in this dryer. The seed was dried uniformly in this dryer because direction of flow of air was changed from top to bottom to bottom to top so it was more efficient than open shade drying.
- This dryer required less space and labour for drying of seeds than open shade drying.
- On increasing the drying air temperature inside the dryer the germination percentage decreased.
- Increasing the drying air temperature of dryer the vigour index of seeds decreased.

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